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ROYAL ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

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GUNS AND AMMUNITION DIVISION

R.A.R.D.E. MEMORANDUM 12/65

The Potton Island Terminal Ballistics Trial Facility

G. R. Nice

[redacted]

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Fort Halstead
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April
1965

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ROYAL ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

R.A.R.D.E. MEMORANDUM 12/65

The Potton Island Terminal Ballistics Trial Facility

G.R. Nice* (B2)

Summary

An account is given of the organisation and capabilities of the R.A.R.D.E. Potton Island Terminal Ballistic Trials Facility with an outline of the wide range of work undertaken from 1959 to 1963.

*Formerly of the Terminal Ballistics Branch

Approved for issue:

S.W. Coppock, Principal Superintendent, 'E' Division

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1. INTRODUCTION

Potton Island, in the estuary of the River Thames (fig. 1), is an out-station of the U.K. Royal Armament Research and Development Establishment (R.A.R.D.E.), which it serves as a large scale experimental firing facility for all types of Terminal Ballistic work associated with high explosives.

From 1958-1960 it served only the Terminal Ballistics Branch of R.A.R.D.E. but in Autumn 1960 it assumed the responsibility for providing terminal ballistic firing facilities for all branches in the Establishment though still remaining an integral part of the R.A.R.D.E. Terminal Ballistic Branch. Before 1958 work on the Island was devoted almost exclusively to work on blast generated by high explosive charges, largely in aid of a nuclear weapons effects programme, while at the end of 1963 it became part of a separate R.A.R.D.E. Trials and Instrumentation Division established as a result of a radical re-organisation within the Establishment.

The results of experimental firings conducted at Potton Island were usually reported initially in R.A.R.D.E. Branch Memoranda which have limited ciculation only to those directly concerned within R.A.R.D.E. Many, but by no means all, of the results were reported or incorporated subsequently in Establishment Reports and Memoranda which had wider ciculation. However, it is thought that a collected account of the facilities available and techniques developed at Potton Island in the period 1959 to 1963 would be of general interest and it is the object of this report to provide such an account.

2. DESCRIPTION OF POTTON ISLAND

2.1 General

The Island (fig. 2) is about 2½ miles long and 1¼ miles wide and is low lying, extremely flat and mostly below sea-level. Spot heights range from about 14 feet above to 10 feet below mean sea level and a sea wall surrounds the Island. The whole of the land was originally farmed and after its acquisition by the War Office (now Army Department, Ministry of Defence) the majority was leased back to the farmer with R.A.R.D.E. retaining full control over three areas:-

(a) Headquarters and Workshops Area
(b) Explosive Magazine and Processing Area
(c) Firing Area

and operational control over the remainder of the Island when necessary.

The great majority of firings are with small weights of bare high explosive (HE) and farming operations can go on unimpeded while these take place. For larger HE firings (over 125 lb) and for any in which metallic components are associated with the HE, a "full cover" is enforced and all persons on the Island must take appropriate shelter.

Before the Island was acquired for Terminal Ballistic work a Public Enquiry was held as a result of which a number of conditions of use for the Island was laid down. The most important of these are that no bombs were to be dropped and no guns fired on the Island and that nothing should be intentionally projected off it by any means

The maximum charge weight which can be fired on the Island is 500 lb.

2.2 Headquarters and Workshop Area

This contains the usual administrative offices to be expected in an out-station of an Establishment such as R.A.R.D.E. with stores, transport section, photographic laboratories, canteen and mechanical and electronic workshops. The mechanical workshop has a small drawing office and in general undertakes relatively minor urgent jobs directly connected with firings, it is supported by the main R.A.R.D.E. workshops at Fort Halstead. The electronic workshop, besides maintaining the wide range of instrumentation needed for trials undertakes the development of new, and the modification of existing, equipment for special purposes and also a limited amount of instrumentation production.

2.3 Explosive Area

This area contains separate magazines for storing up to 10,000 lb of bulk explosive, prepared charges and detonators of all kinds needed for firings, together with facilities for casting, pressing and machining explosives. Casting capacity is up to 200 lb at a time with up to 64 lb capacity for machining. RDX/TNT, baratol, EDC1 and various plastic explosives (PE) are handled. It is customary for only empty charge components to be supplied for trials and for the explosive filling to be done at Potton Island. Facilities for X-ray inspection of charges had been installed just prior to the publication of this memorandum.

2.4 Firing Area

This is located at the widest part of the Island and gives a safety radius of about 1000 yards. There are four main control and instrumentation buildings around a perimeter road each with its own trial specialities. These are:

- F1 Blast measurement and shaped charges.
- F2 Rod projectors and explosive metal forming.
- F3 Fragmentation work of all kinds of rod warheads.
- F4 Blast response and high altitude blast.

There is a most comprehensive intercommunication system and if necessary virtually any firing can be controlled and instrumented from any building.

Each of the firing area buildings has its own individual firing area associated with it (fig. 3). These areas are arranged so that any building may conduct firings involving up to a specified weight of bare HE without the necessity of personnel in other areas going under cover or being restricted in any way. The guiding principles for establishing these areas and weights of HE were that there should never be more than $\frac{1}{2}$ p.s.i. over pressure on any building or more than $\frac{1}{4}$ p.s.i. at the edge of an area.

In all firings a comprehensive system of flags, sirens and look-outs ensures that the state of firing and cover in any area is immediately apparent and that appropriate areas are clear of personnel in the open.

For all firings a Trials Officer and a Range Officer are nominated. Both must be members of the Potton Scientific Staff; the former ensures that all explosive and other stores and equipment are correct and the latter that all safety requirements are observed closely. The Range Officer is required particularly to take note of

meteorological conditions and not to permit firings if there is likelihood of 'distant damage' by atmospheric conditions focussing blast, or if it is not possible for look-outs to see the whole of their specified areas clearly.

In assessing the possibility of distant damage he can obtain guidance from the nearby Atomic Energy Authority Firing Range at Foulness Island which has an accoustic ray simulator giving an indication of likely focussing when fed with data from balloons sent up by the Air Ministry Meteorological Office at the Proof and Experimental Establishment at Shoeburyness.

2.5 Major Facilities

2.5.1 General

The normal firing facilities of Potton Island are described in appropriate sections of this report dealing with specific types of firings but there are a few major facilities worthy of separate mention.

2.5.2 Cased Charge firing building

This building (fig. 4) is a re-inforced concrete structure in which cased HE charges of up to 16 lb may be fired without the necessity for laying down a full cover over the whole Island (see 2.1).

The building was completed late in 1963 and at the time of writing (June 1964) had yet to be fully proved. A novel and, it is thought unique, feature of the construction is that a number of patch and vibrating-reed strain gauges were attached to 78 selected re-inforcing rods in the course of construction. This will make it possible for a full strain history of the building under explosive loading to be recorded throughout its life, provided effort is available to take appropriate readings.

2.5.3 Blast Pad

This (fig. 5) is a flat concrete area about 108 x 54 ft with a smooth granolithic finish with facilities for mounting air and ground blast gauges. It is intended for basic study of the expansion of blast waves over a rigid surface and will eliminate differences in results due to differing soil conditions observed by many workers on this subject. As with the Cased Charge building it was not completed until late 1963 and has still to be proved and brought fully into use.

2.5.4 High Altitude Chamber (Fig. 6 - Ref. 1)

This is a steel cylinder about 25 ft long by 10 ft in diameter which can be evacuated to 0.2 - 0.1 mm Hg., simulating pressure conditions up to about 200,000 ft altitude; (there is no temperature control) H.E. charges varying from 1 lb at sea-level to 8 lb at high altitude conditions may be fired inside the chamber with a safety factor. Pressure gauges and probes and, later, a short range optical Schlieren system are used to study close-in blast parameters. The chamber may also be used for the collection of gas samples after detonations.

2.6 Staff

The total Terminal Ballistics Branch staff at Potton Island was about 120 of which about 20 were Experimental Officer and Scientific Assistant Grades responsible for all aspects of trials work, that is physical conduct of trials, instrumentation, explosive charge processing etc. plus instrumentation maintenance and construction. They are supported directly on trials work by about 30 Industrial Staff; the remaining Potton Staff being employed in Stores, Fire/Patrol, MT and other ancillary duties necessary because of the outstation status of the Island.

The day-to-day running of the Island is in charge of a Chief Experimental Officer with a Senior Experimental Officer as his Deputy. All the staff worked in very close collaboration with Scientific and Engineering Staff at R.A.R.D.E. Fort Halstead.

As a matter of policy each member of the staff developed a "speciality" (see 2.4); in addition to conducting the majority of trials requested in this particular area each pursued his own line of work independent of specific trials under the direction and supervision of Fort Halstead Scientific Staff. This arrangement resulted not only in progress in the various areas of Terminal Ballistics but in the development of better trial techniques and more "satisfied customers" and also enhancement of staff morale. The experimental staff could feel that they were actively co-operating with those who requested trials and not merely following trial instructions.

In addition to their work actually on the Island, Potton staff have provided blast instrumentation and actively assisted in overseas trials in Australia, Germany and Canada: on numerous occasions they have provided special instrumentation at other Ranges in UK, (e.g. Pendine, Lulworth and Woolwich) using the two mobile recording vans available at Potton.

Also, as well as providing material assistance, Potton staff are frequently called upon to give advice to other Establishments on matters of blast and other specialised instrumentation techniques and equipment.

3. INSTRUMENTATION

3.1 General

Potton Island is adequately equipped with conventional still and high speed (Fastax and Fastair) framing and streak cameras and with normal electronic apparatus (e.g. Cathode ray oscilloscopes and microsecond counters); in addition there are a number of specialised items of instrumentation, brief details of which are given below.

3.2 Blast Recording

Transducers and associated equipment are available for recording blast pressures from less than 1 p.s.i. to over 700 p.s.i. with durations from less than 1 m sec. to several seconds. The transducers vary in configuration according to application but most consist essentially of a stack of quartz crystals held between flexible diaphragms. The most commonly used is designated the H3 gauge in which the crystals are mounted in a streamlined "hatchet" about 3" x 9". Details are given in Refs 2 and 3. Gauges with wire and semi-conductor strain elements are also used.

A 12 inch diameter shock tube is being installed for calibrating gauges and evaluating new designs.

The recording equipment used is either Southern Instrument "Minirack" equipment modified to give higher frequency response and better long term stability or a 4-channel cathode ray recording equipment developed at Potton Island.

The equipment in use is considered to be accurate for "side-on" measurements but no entirely satisfactory transducer is yet available for "face-on" blast measurements. With all piezo-electric materials the problem is complicated by an accelerometer effect which occurs when the transducer element is displaced by the blast wave impact and also by internal reflections of shock within the element. Work is in progress to develop transducers which will eliminate or minimise these effects.

In addition to relatively sophisticated gauges intended to measure both amplitude and duration of blast waves simple, "time of arrival", gauges are widely used. These consist of barium titanate crystals mounted in a holder which will give an electrical signal when a blast wave passes them. Pairs of gauges at fixed distances apart are normally used to give the blast wave velocity from which peak blast pressure may be calculated from the formula:-

$$\frac{P}{P_o} = \frac{2\gamma}{\gamma+1}\left(\frac{V^2}{C_o^2} - 1\right)$$

P and P_o are peak blast and ambient pressures; V, blast wave velocity; C_o sound velocity in free air; γ, ratio of specific heats of the gas involved.

Potton Island has also made considerable use of an optical technique for "visualising" blast waves. In this a black and white striped screen is placed behind the charge and photographed with a high speed camera during the charge explosion. The change in refractive index at the blast front produces an apparent discontinuity of the stripes and the movement of the front is easily seen.

3.3 Kerr Cell Cameras (Ref.4)

A Kerr cell is an electro-optical device whose light transmitting powers can be radically changed by the application of a high voltage across it. By suitable design such a cell can be used as a very high speed camera shutter with exposures in the sub-micro second region. Two 12-channel cameras are available at Potton, one short range for use out to about 15-30 feet and one long range for use at 70-200 feet. Both have minimum exposure times of 0.1 μ secs and the minimum possible time for a total of 12 exposures is about 5 μ secs.

These cameras have been used extensively for studies on the propagation of detonation in explosives.

3.4 "C4 Camera"

This is a rotating mirror - stationary film type of camera which will take 140 pictures at a maximum framing rate of 100,000 per second. The camera is of joint ARE/AWRE design and despite its weight of about 5 cwt it is relatively easy to manoeuvre and set up, being mounted on a rubber tyred carriage. The camera is often used with argon flash bombs to provide illumination. These bombs consist of a light cardboard and cellophane container filled with argon and containing a small explosive charge which, when detonated, produces an intense flash, lasting up to 40 microseconds giving the high level of illumination required.

3.5 Argon Lamp Chronographs (ALC) (Ref.5)

These are 40-channel instruments used for timing purposes. They consist essentially of a battery of 40 argon lamps, normally in a near - quiescent state which produces a faint trace on photographic recording paper on a drum camera. An event, such as the breaking of a wire by an explosively projected fragment or the making of a contact, is made to apply a pulse to a lamp causing it to brighten momentarily and give a dark spot on the appropriate trace. The paper speed being known the distances between spots or between a spot and a reference zero give times. In some applications the chronograph is used "in reverse"; that is with the lamps bright initially and reduced to quiescence by the events.

The chronographs are over 15 years old and less accurate than electronic counters now available, but their ability to record on 40-channels makes them extremely valuable, particularly in fragmentation work when it is often necessary to record the velocities of a large number of fragments. Paper speed can be up to 1000 ins per second and a high time resolution is possible.

3.6 Flash X-ray Equipment

The latest major acquisition on the instrumentation side at Potton Island is a 4-channel 300 KV flash X-ray equipment. It is a model made by the U.S. Field Emission Corporation and has a minimum pulse width of about 0.1 ft/sec. The penetrative power is about 6 ins of aluminium and the tubes with their associated pulsing circuits can be operated up to 100 feet from the control panel. It is planned to use the equipment to study phenomena which are hidden from normal cameras by smoke, explosion products, metallic components etc.

4. TYPES OF TRIAL UNDERTAKEN

4.1 Continuous Rod Warhead

In this type of warhead for the attack of airborne targets a cylinder formed of rods welded together at both ends is expanded by a central explosive charge into a fast-moving hoop which will damage any target with which it comes into contact. It is important that the hoop should retain continuity to as large a radius as possible, ideally to the theoretical maximum radius, (this means in effect that the rods forming the hoop should not break at the welds or 'hinges') and also that the hoop should have as high a velocity as possible.

A technique for evaluating experimental warheads in the light of these requirements was developed at Potton Island in conjunction with Warhead designers and has been used for upwards of 30 firings.

The warheads are mounted with their axes vertical on wooden platforms with their centres about 4 ft 6 ins above ground level. Surrounding the warheads on a circle of radius approximately that of the theoretical maximum hoop radius of the warhead, are a number of mild steel plates each 6 ft by 3 ft by 1/16 inch thick mounted with their short sides vertical; the horizontal centre line of each being marked with a 1 inch wide painted white line and located at the same height above the ground as the centre of the warhead. The plates usually occupy about 50% of the circumference and the remainder is taken up largely by strawboard packs for recovering rods, sections of aircraft and target bars of various thicknesses. High Speed

Fastax cine cameras are used to observe the development and flight of the rod hoop through a free gap in the target arena, a bank of a hundred or more PF 100 flash bulbs being used to illuminate the rods. The average velocity of the rods is measured by means of an ALC (para. 3.5) recording the times between the instant of detonation and the rods striking velocity screens fixed to the front of each target plate. Rod retardation is measured by a radial line of thin aluminium foil flash-posts. When a rod strikes a post a bright flash occurs which is recorded on the high speed cine film and in, addition, the posts are connected to the ALC giving two sets of space-time measurements for the rods. In general retardations measured by the two methods are in very good agreement.

A typical trial lay-out before and after firing is shown in Fig. 7, while Fig. 8 and 9 show witness plate damage and rod development as recorded by a Fastax camera. The results obtained in the continuous rod warhead firings at Potton Island have given much valuable information to warhead designers.

4.2 Rod Projectors

In addition to the firing of complete continuous rod warheads Potton Island has developed facilities for firing single rods from high explosive projectors. Work of this nature was taken over from the R.A.R.D.E. Warhead Design Branch quite late in the period covered by this report and it is a good example of Terminal Ballistic Research conducted largely by Potton Island staff virtually as an independent effort.

The object of the work is to investigate the damage produced by rods of varying sizes and mechanical properties on various targets at a range of impact velocities, in order to determine optimum parameters for actual warhead design.

The 'standard' rod projector evolved by the R.A.R.D.E. Warhead Design Branch after several hundred empirical firings consists of a straight 5 ft rod with an extension piece at each end (making an overall length of 5 ft 9 ins) located between two mild steel guard plates 1 inch wide and the same thickness as the rod. A perspex attenuator sheet of appropriate thickness is interposed between this metal assembly and the explosive charge of PE. The explosive charge is contained in a wooden box and is initiated at one end; the rod is projected from the charge by a "wiping" action. By varying parameters (e.g. height/depth ratio of explosive, thickness of perspex sheet) it is possible to obtain a wide range of rod velocities with an accuracy of ± 100 ft per second.

A layout has been constructed at Potton Island for rod projector trials (Fig. 10) in which rod movement may be followed by Fastax cameras and flash posts as for the complete CR warhead firings (see 4.1 above) and the effects of strike on various targets noted.

A number of preliminary firings have been made using the standard projector and a comprehensive programme of work formulated. This would cover the points mentioned in the object of the work outlined above and would include a study of methods of raising substantially the velocity at which rods could be projected without too much break-up.

4.3 Shaped Charges

Shaped charges, each consisting essentially of a metal cone which is formed into a very high velocity particulate 'jet' by a high explosive charge have a wide application in missile warheads and other projectiles especially for the attack of tanks. Over 500 rounds of more than a dozen different types of shaped charge have been fired at Potton Island in the course of development of specific warheads and in programmes of more basic work on the attack of armour. The firings have been made with one or more of the following specific objects:

(1) to assess the energy in the jet from the crater formed by a shaped charge in semi-infinite armour to give basic data for lethality assessments,

(2) to assess performance against various specific standard targets,

(3) to assess fragmentation and damage produced behind specific targets, including armour of various hardnesses.

In addition to firings to assess the macroscopic effects of shaped charges of various types a very limited amount of basic work has been done on the production of high velocity particulate jets by processes similar to those used in shape charges.

4.3.1 Semi-infinite targets

The charges are supported on a simple wooden frame-work at an appropriate distance (stand-off) above a stack of rolled homogeneous armour (RHA) plates of known composition and properties, 24 or more inches high (Fig. 11). The thickness of the individual plates varies with availability but for convenience they are normally 60 mm and 150 mm thick. After firing the stacks are dismantled, the holes or craters in each plate cleared of liner material and the crater diameters measured at 1 inch intervals of depth using a vernier caliper with 'toes' shaped so as to be able to follow sharp variations in profile. At each depth diameters are measured to ± .05 ins in two directions at right angles. Crater volumes in each plate are also measured by setting the plate horizontally on a thin sheet of plasticine spread on a level surface and running in water from a burrette; the accuracy being ± 1 ml.

From the measurements on individual plates a complete hole profile for each charge is built up; this gives an indication of the performance and it can be used for assessment of the lethality of the charge against specific targets.

In practice it is usual to make the stacks of plates of a sufficient size that all shaped charges in a particular series can be fired sequentially before the plates are dismantled. This speeds up the experimental work considerably and avoids the complication of possible differences between plates.

4.3.2 Finite Standard Targets

To assess the performance of a shaped charge against a specific target it is simply fired at the required angle and stand-off and the resulting damage noted as a 'defeat' or not. If the charge is such as to heavily defeat, or 'overmatch' the target mild steel plates or strawboard packs (see 4.3.3) are used as witness material to measure the degree of overmatch.

The targets most commonly used are the "Tripartite Standard Targets" which were agreed at a UK-US-Canadian conference in Ottawa in 1957 they are:-

Single	150 mm RHA at 60° angle of attack
Double	50 mm RHA - 6 ins air - 100 mm RHA at 60°
Triple	10 mm RHA - 13 ins air - 1 in. mild steel - 13 ins air - 80 mm RHA at 65°.

The targets are illustrated in Figs 12 and 13.

In addition a number of firings have been made with high overmatch conditions using 14 mm and 30 mm plate to investigate the attack of armoured personnel carriers.

4.3.3 "Behind-armour" effects of shaped charges

A shaped charge jet, by its very nature, is highly directional and does not in itself have any great damaging potential other than in its direct path.

Much of the lethality of shaped charges comes from secondary fragments spalled off a target as a result of the jet impact. To assess this aspect of lethality strawboard packs to collect fragments etc. are erected behind a target against which a shaped charge is fired. These packs have been standardised at Potton Island and consist of 19 sheets of 40 ins x 30 in. x .16 in. strawboard (or cardboard) of a standard density (9 oz/sq ft) and to Specification DEF81 banded together with metal strips using a convenitional case banding machine. After a firing the packs may be broken down and fragments recovered and weighed. The position of each fragment can be recorded and its penetration into the pack will give a measure of its energy on impact.

For convenience the packs are normally erected vertically, even when used in conjunction with the angled tripartite targets, in a 3 x 3 arrangement and the bottom left hand corner, facing the packs taken as a reference point for recording fragment position. However the packs can, of course, be set at any angle if there is a reason for doing this.

4.3.4 Production of particulate metallic jets

The object of these firings was to investigate the possibility of producing high velocity particulate jets from grooved, thin wall, aluminium tubes filled with high explosive. The tubes used were of 3 ins dia., 5 mm wall thickness x 4 ins long with circumferential and longitudinal grooves, the internal angles of the corrugations being 45° and the width peak to peak about 3 times the wall thickness. Plastic explosive was pressed into the tubes and they were fired suspended vertically and horizontally against a black background the explosion being photographed at 4 sec intervals with Kerr Cell Cameras, the self illumination of the hot fragments being sufficient to record on the photographic plates. Steel and aluminium witness plates were positioned near the charge.

The photographs and the appearance of these plates gave a positive indication of jet formation, the jet velocity being of the order of 5 mm per microsecond.

4.4 Explosive forming

Potton Island has conducted a considerable number of firings in aid of basic and applied work on explosive working of metals. With this technique metallic components may be shaped into a die or mould, cut, embossed or welded by the blast wave from a explosive transmitted by air, water sand plasticine (modelling clay) or rubber.

Though explosive forming cannot be classed strictly as Terminal Ballistics the nature of the site at Potton Island and the expertise of the staff made it an ideal location for this type of work.

As a result of a policy decision towards the end of 1962 the effort on explosive forming was reduced with the intention that it should eventually be confined to advising other users on techniques etc., however the expertise and facilities for experimental explosive forming will continue to exist at Potton Island should the need to use them arise in the future.

4.4.1 Basic studies on explosive forming

The most important of these involved the determination of scaling factors involved in correlating deformation of metal diaphragm with charge weight. The test pieces used were of copper and of mild steel sheet in the form of a circular diaphragm about 7 ins in diameter clamped under standard conditions across the open end of a cylinder which could be evacuated. The assembly was lowered into a hole in a massive concrete foundation covered with steel plates so that the diaphragm became part of a virtually infinite rigid reflecting surface giving constancy of experimental conditions. The explosive charges were of pressed spheres of RDX/TNT, 60/40, of weights from 2 to 16 ozs supported on a light perspex tripod. (fig.14) After firing the maximum, or central, deflection of the diaphragm was used as a measure of deformation.

In other basic work the motion of explosively loaded diaphragms was followed using a high speed Fastax camera. 10 inch diameter copper diaphragms of 1/16, 1/8 and 3/16 ins thickness were used and water was used to transmit blast waves. Reasonably accurate deflection - time relationships were established leading to calculations of bending wave velocities and rates of strain which are in good agreement with theory.

4.4.2 Applied studies

These have included the sizing and shaping of small tubes and other components, embossing and 'dimpling' of sheet, forming 6 ft diameter radar dishes and large pressure vessel ends, the closing of atomic reactor fuel-element cans, the fixing of end connectors on to large capacity electric cables and the explosive welding of similar and of different metals.

Of necessity the approach to each problem was largely empirical: in every case the appropriate charge and transmitting medium for the blast and also the support for the work piece had to be determined. Any detailed description of this is outside the scope of this report.

4.5 Fragmentation

4.5.1 Projectile fragmentation

In the assessment of the lethality of any fragmenting shell, mortar bomb or warhead designed for anti-personnel use it is essential to have an accurate knowledge of the characteristics of the fragments produced on detonation; that is the spatial distribution, mass and velocity of the fragments. Potton Island used a standard method for obtaining this information.

The projectile under investigation is suspended horizontally and surrounded by a rectangular box of targets; the size of the box varying with the size of the projectile; for a 105 mm FBA shell it is about 10 ft x 10 ft x 20 ft. Three of the sides consists of three strawboard packs (see 4.3.3) supported on a suitable framework and the fourth is constructed from 3 inch thick standard 9 ft x 9 ft wooden targets. To give a more clear indication of 'strikes' the wooden targets are normally covered with a single layer of strawboard and to ensure that only direct strikes hit the walls of the box $\frac{1}{2}$ in. mild steel plates of suitable height, usually about 4 ft, are used anti-ricochet screens beneath the projectile.

The strawboard targets are marked off in five degree zones from $0^{o}C$ (nose of projectile) to 180^{o} (base) and a number of wire velocity screens are fixed to them so that the time of flight of a fragment from projectile detonation to target strike can be measured using the ALC and hence strike velocities deduced. Figs 15, 16 and 17 show a typical layout (for a 105 mm shell).

After firing the targets are dismantled and the strawboard packs broken down. The first card of each pack is struck by many small fragments, pieces of wire from leads and other debris of no penetrative power or significance; these are discarded but any fragments of reasonable size are recovered, weighed and entered in the appropriate 5 degree zone on recording sheets. On the second card each hole is numbered also and entered on the sheets. Each fragment actually recovered in the second or subsequent sheets is entered under the hole number in the second sheet through which it had originally passed. Allowance for secondary break-up within the packs is made by assuming that all fragments passing through the same entry hole were originally a single fragment. Degree of penetration is recorded as the number of the card in which a particular fragment remained embedded on disassembly of the packs. Each fragment is weighed to .01 oz; any less than .01 oz being classed as "small" and the total weight of "smalls" for each 5 degree zone is recorded separately.

The wood targets are examined and a record made of "strikes" "deep strikes" (i.e. penetration greater than 1 in.) and "throughs".

The full tabulation of results is used to calculate mean areas of effect and other lethality criterion.

With appropriate modifications (e.g. to size of target layout) the above method has been used successfully with field artillery shell, U.K. and foreign anti-personnel mines, mortar bombs, and with fragmenting missile warheads and warheads with preformed fragments of various types.

4.5.2 Other techniques

In addition to the standard technique outlined above special techniques have been devised to meet unusual fragmentation requirements. An example of this was the estimation of safety distances needed to guard against possible damage or injury on firing ranges by the accidental, or premature detonation of an anti-tank missile in flight. It was particularly to know the possible danger zone behind the missile along its flight path. Because of the size of the missile construction of a standard target would have been very laborious but the problem was simply solved by laying out strawboard packs with velocity screens and also target boards flat on the ground and suspending the missile, nose-up, between two poles about 30 ft above the ground. After detonation of the missile the targets were examined in the usual way and the required information obtained.

Somewhat similar procedures were adopted to determine if the intentional detonation of a missile warhead would be certain to destroy the motor in the event of a uncontrollable round and also to develop explosive break-up units to destroy "rogue" target drones and aircraft. A notable example of this was a break-up unit for a radio-controlled Canberra aircraft.

Experience gained in fragmentation work has been applied to the projection of single fragments by explosive means and a technique has been developed by which such fragments may be projected at up to 18,000 ft per second without break-up.

4.6 Blast measurement

Some brief indication of blast recording equipment capabilities was given in section 3.2 the present section gives some account of the application of the technique available. As with the fragmentation work knowledge and experience gained in blast measurement is being actively applied, in this case to enhance blast effect by changing the charge casing and charge configuration.

4.6.1 Measurements in air

Trials conducted at Potton Island which involve the measurement of air blast fall into two fairly distinct classes. The first covers firings of bare explosive charges for basic work on blast generation and propagation and also for the calibration of blast gauges, since the blast pressures to be expected at given distances from standard charges are well known. For this type of work a uniform 'reflecting surface' for blast waves which strike the ground is desirable and the blast pad described in 2.5.3 was constructed with this in mind. The second class of firing covers the measurement of blast from warheads, and other 'cased' charges, to determine an equivalent bare charge weight (see below) for the warhead and also the incident blast loading on targets deployed around the warhead.

The details of the experimental layout used naturally depend on the warhead under test and on the exact information required; gauges (see 3.2) are mounted in appropriate positions and if there is a possibility of their being struck by flying fragments etc. short lengths of steel tubing filled with sand are positioned in front of each at such a distance as to give protection from strikes with negligible blast shielding. The gauges are connected by co-axial cable to appropriate recording equipment. On firing a common pulse, usually from an ionisation probe fixed to the warhead initiating system, is injected on to all recording channels to give a zero time on the records.

Pressure-time curves obtained are measured and values of peak over-pressure, positive impulse, positive duration and shock transit time calculated; these are used to deduce equivalent bare charge weights and target loading.

The equivalent bare charge (W_e) of a cased munition may be defined as that weight of unconfined explosive which will generate, at the same distances, approximately the same values of peak pressure and positive impulse as those observed from the munition. Its determination is based on a comparison with known bare charge data. There is no unique value of W_e since it may vary with distance and with the particular criterion adopted for its definition. Generally speaking a mean value of W_e which holds for a range of distance without serious error may be deduced.

W_e is very useful for making comparisons of the likely damaging effect of different types of warhead and for establishing safety distance for storage etc.

4.6.2 Measurements on the ground

A particular case of blast loading is that produced by a charge on the surrounding ground. Potton Island have produced a prototype ground blast gauge using the element from an H3 blast gauge set in a brass holder in a concrete block with its surface flush with the ground. These have been used satisfactorily in firings to investigate certain anomalies observed with mine clearing charges and on firings of a FAX (fuel-air-explosion) system.

4.6.3 Measurements in enclosed spaces

It is often of interest to know the rise in pressure within a closed compartment which is struck by a shaped charge jet and Potton Island have made measurements of this type of pressure rise in tanks and in replica targets simulating aircraft structures. The problem of obtaining a transducer for such measurements which will have a high enough frequency response to follow faithfully the inevitable pressure oscillations which occur when a box-like target is struck by a shaped jet, and which is robust and relatively cheap has not yet been solved satisfactorily; robustness and cheapness are necessary since the transducers are very liable to damage from "near misses" by jet or target fragments and to destruction by direct hits. However transducers of sufficient accuracy to give useful results have been used satisfactorily.

In the tank trial gauges with single crystals of barium titanate or lead zirconate were used in pairs at four points in the crew compartment of a Comet tank. These were connected to a galvanometer recorder housed in an instrument trailer, and despite a heavy loss of gauges and cables struck or cut by fragments reasonable pressure time curves were obtained.

For the aircraft target both piezo electric gauges of a similar design and also strain gauges were used. The outputs from both types of gauges were recorded in suitably modified minirack equipment and, in one later trial, the strain gauges were fed into a low frequency galvanometer recorder.

The results obtained showed that the strain gauge/galvanometer combination gave the best records and indicated that quantitative measurements of the transient pressure rise on box type targets attacked by shaped charges can be made although further work is necessary to improve experimental techniques.

4.7 Blast studies on models

A very useful technique in the study of the behaviour of structures and other targets when subject to high levels of blast loading from either atomic or conventional explosions is the use of small models which are subjected to much lower levels of blast. For the satisfactory application of this technique a knowledge of appropriate scaling laws is obviously essential and Potton Island staff have carried out a number of firings with charges from 1 to 4000 lbs to deduce such laws. (Charges in excess of 500 lbs were fired at a neighbouring range). Simple cones and cylinders of various sizes and thicknesses and also full size and model missile bodies have been subjected to blast from a wide range of high explosive charges and, taking the first visible sign of damage as a criterion, it has been shown that satisfactory sealing is possible.

With some firings against missile bodies anomalous results were obtained which were resolved when it was discovered that because of permissible manufacturing tolerances the actual thickness of the sheet metal used to make the models differed by some 17% from the nominal 16 SWG; this is a good indication of the care which must be taken in this type of model work.

Model techniques have also been used most satisfactorily to determine the response of magazine interceptor traverses to blast loading and also to obtain information to assist the design of explosive processing buildings.

Models were made of the structures (using sand for the traverses and concrete for the buildings) and their response to small scale explosions followed with medium speed cine cameras.

4.8 Explosive initiation

The majority of work on explosive initiation can be done with small bare charges and this is usually undertaken at R.A.R.D.E. Fort Halstead where facilities exist for firing up to 3 lbs of bare high explosive. Circumstances arise however when it is desirable to fire larger charges or charges with which metal components are associated and a number of these have been made at Potton Island in aid of studies of anti-personnel mine and continuous rod warhead initiating systems and to study exploder failures etc.

As with several previous types of trial the detailed experimental conditions were peculiar to the actual item under investigation but extensive use has been made of both long and short range Kerr cell cameras to follow the progress of detonation in various parts of the system.

On at least one firing thermocouples were inbedded in the explosive filling of an experimental warhead during casting to determine whether an exploder unit (which was not expected to detonate the filling) had caused any appreciable rise in temperature which might render the warhead unsafe to approach for examination.

4.9 Response of armour plate to HESH attack

In attempts both to elucidate the contribution of possible variations in the actual target plates to anomalous results observed in dynamic firings of HESH shell and also to obtain a correlation between HESH damage and physical properties of the plates, Potton Island have made a large number of static firings of identical cylindrical $8\frac{1}{4}$ lb HE charges in contact with a number of thick armour plates. The physical properties of the plates were known and they had been inspected ultrasonically to determine the presence of inclusions and other defects.

The plates were supported vertically in such a way that the trajectory of scabs (if any) produced by the charges could be followed with a Fastax camera, to determine scab velocity and so that the scabs could be recovered in strawboard packs. The arrangement is shown in Fig. 18 and a full description and results is in ref. 6.

Work on this topic is continuing in an attempt to find the energy involved in detailing a scab. This is being done with a similar experimental arrangement but with pre-formed scabs and plate recesses so that the explosive has merely to project the scab not to detach it.

4.10 Illuminating devices

Potton Island have made firings to assist other R.A.R.D.E. Branches in the development of star-shell and of large photographic flash bombs. These posed virtually no problems; for the shell, the requirement was to determine the optimum size of a gun powder charge used to eject the star container and its parachute and only high speed camera coverage was required. For the flash bomb photometric records of intensity and duration of flash were taken by the sponsoring Branch while Potton Island again provided high speed camera coverage to determine flash growth decay and symmetry and also measurement of free air blast pressures using techniques similar to those outlined in section 4.6.1. For photometric reasons the bombs had to be detonated about 30 feet off the ground necessitating the mounting of the blast gauges at a similar height. This was accomplished without any particular difficulty using a framework of standard tubular steel scaffolding; the set-up was proved using 32 lb high explosive firings before the flash bombs were fired.

5. CONCLUSION

The foregoing gives a fairly complete account of the organisation and accomplishments of Potton Island during the time it served as the Terminal Ballistics Branch Experimental Facility. It indicates the very wide range of experimental explosive firing which can be handled by a small competent team who are interested in what they are doing.

No useful purpose would be served by enumerating in detail all the trials carried out since the effort involved varied very widely ranging from a few man-hours in the firing of a small bare charge for some basic information to a few thousand man-hours for a large scale fragmentation firing.

It is however of interest to record that in the period covered by this report about 175 trial requests (each covering anything from one to twenty or more actual firings of varying complexity) were received by Potton Island. Of these about 56% were from outside the R.A.R.D.E. Terminal Ballistics Branch.

6. ACKNOWLEDGMENT

Acknowledgments are due to all the staff of R.A.R.D.E. Potton Island without whom, (obviously) this report could not have been written.

REFERENCES

1. R.A.R.D.E. Memorandum 39/64
2. A.R.D.E. Memorandum (MX) 54/60
3. R.A.R.D.E. Memorandum (M) 38/64
4. A.R.E. Report 22/53
5. A.R.E. Report 19/51
6. R.A.R.D.E. Report to be published

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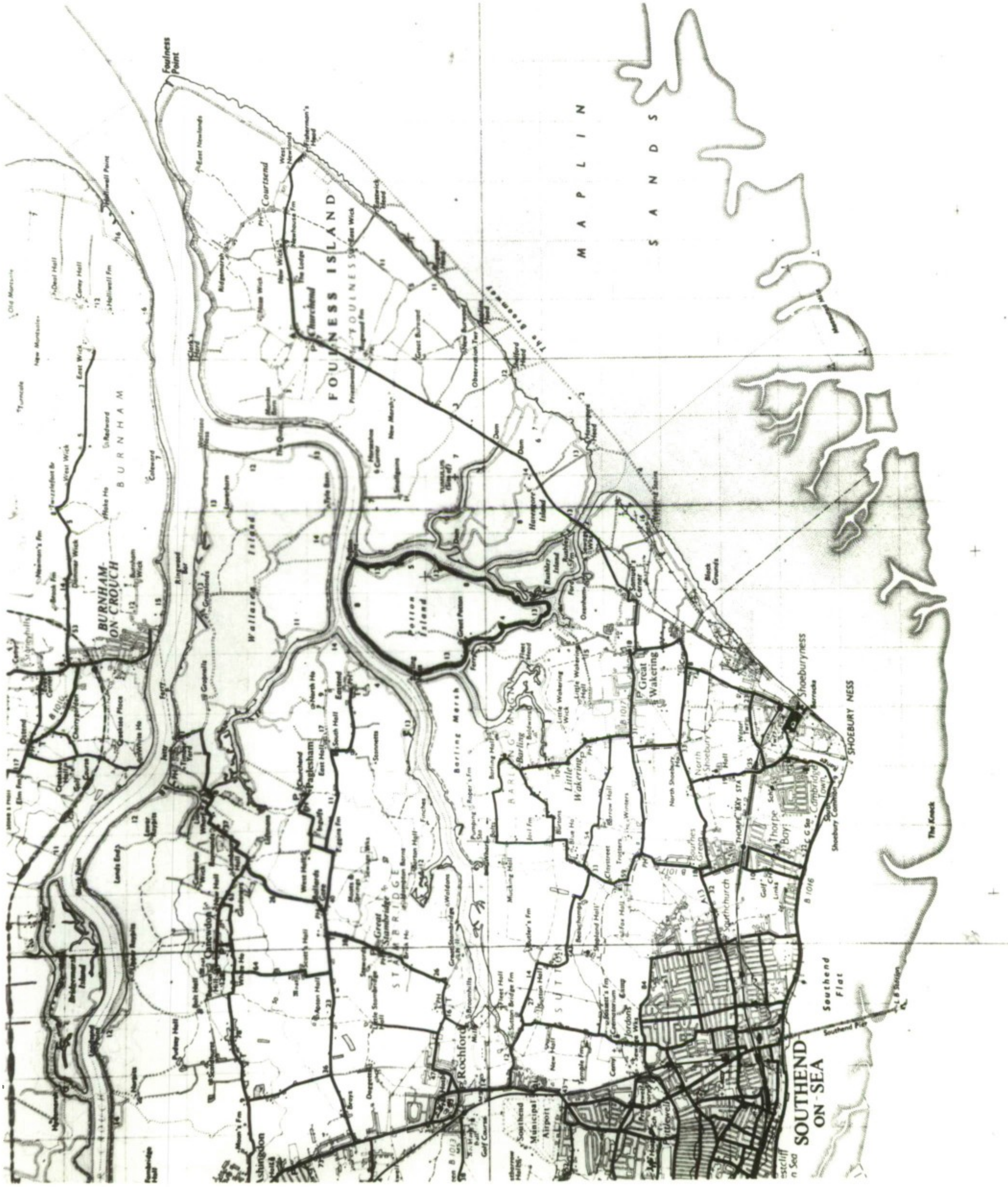
FIG. 1



LOCATION OF POTTON ISLAND

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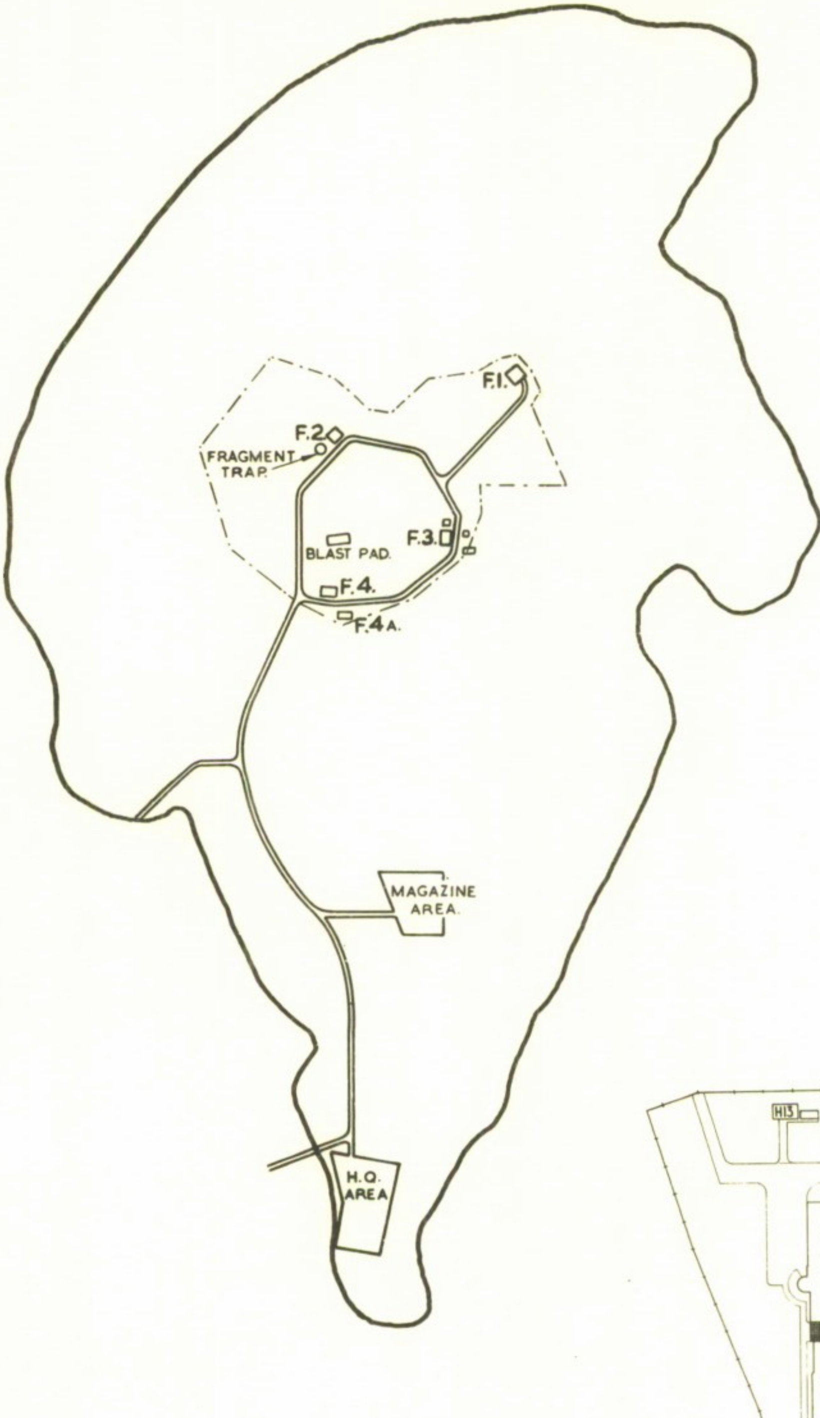
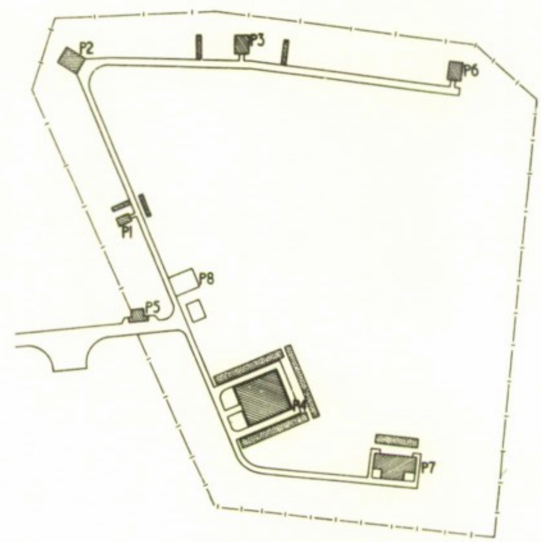
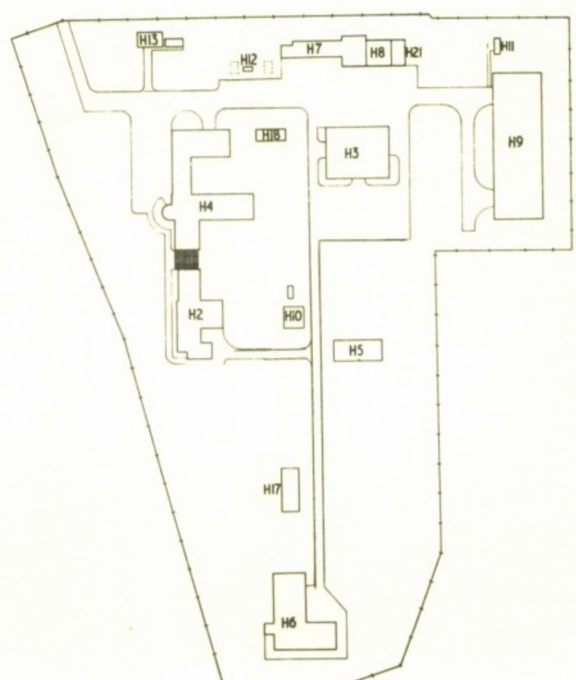
FIG. 2



POTTON ISLAND.



EXPLOSIVES PROCESS AREA



HQ. AREA

LAYOUT OF POTTON ISLAND

FIG. 3a

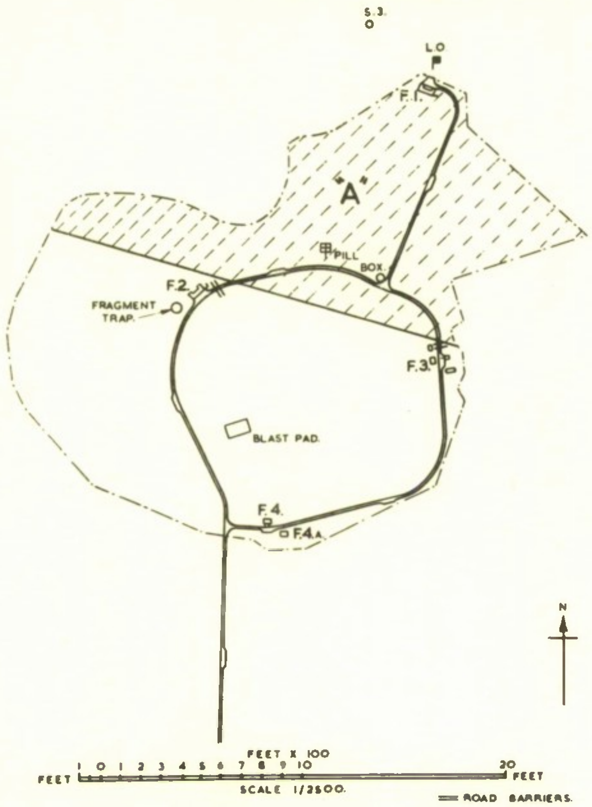


FIGURE - AREA "A"

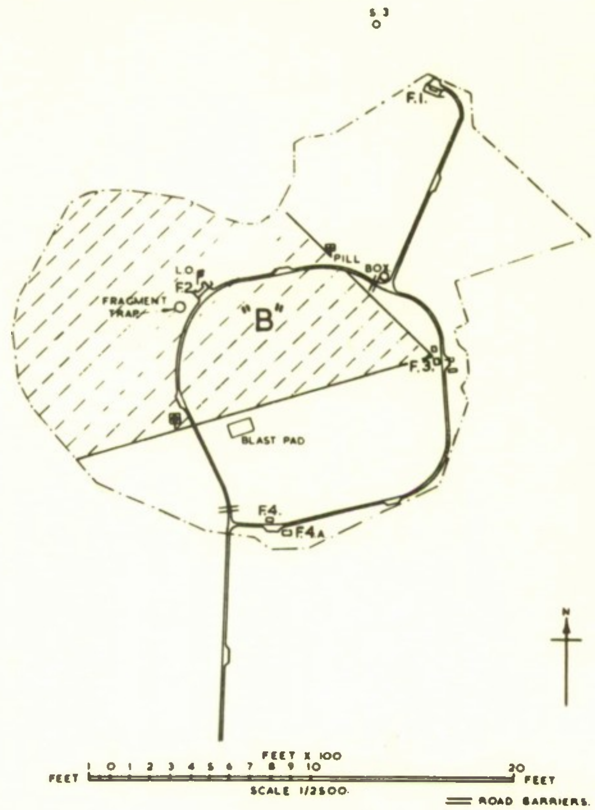


FIGURE - AREA "B"

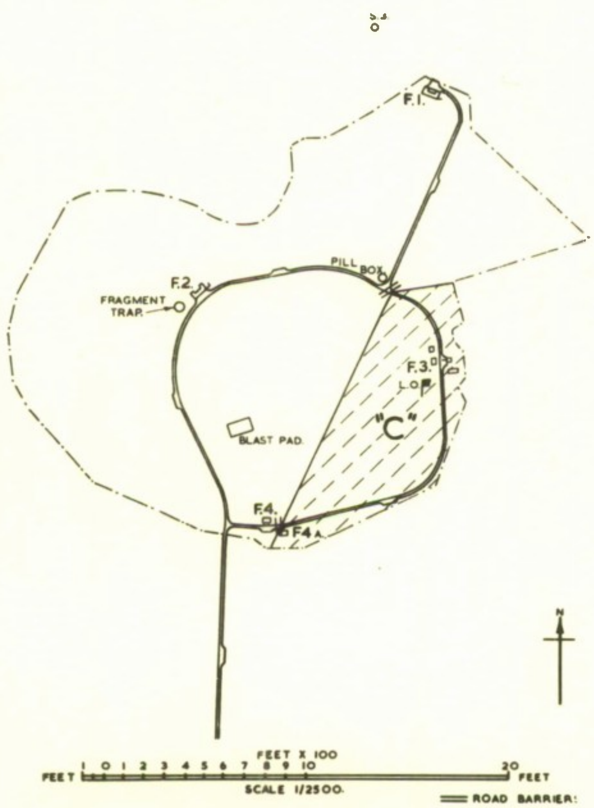


FIGURE - AREA "C"

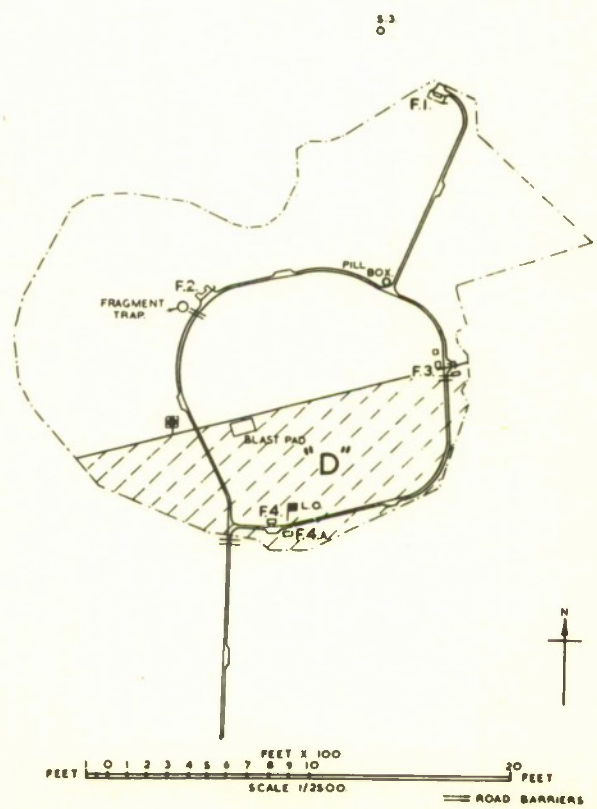


FIGURE - AREA "D"

INDIVIDUAL FIRING AREAS

FIG.3b

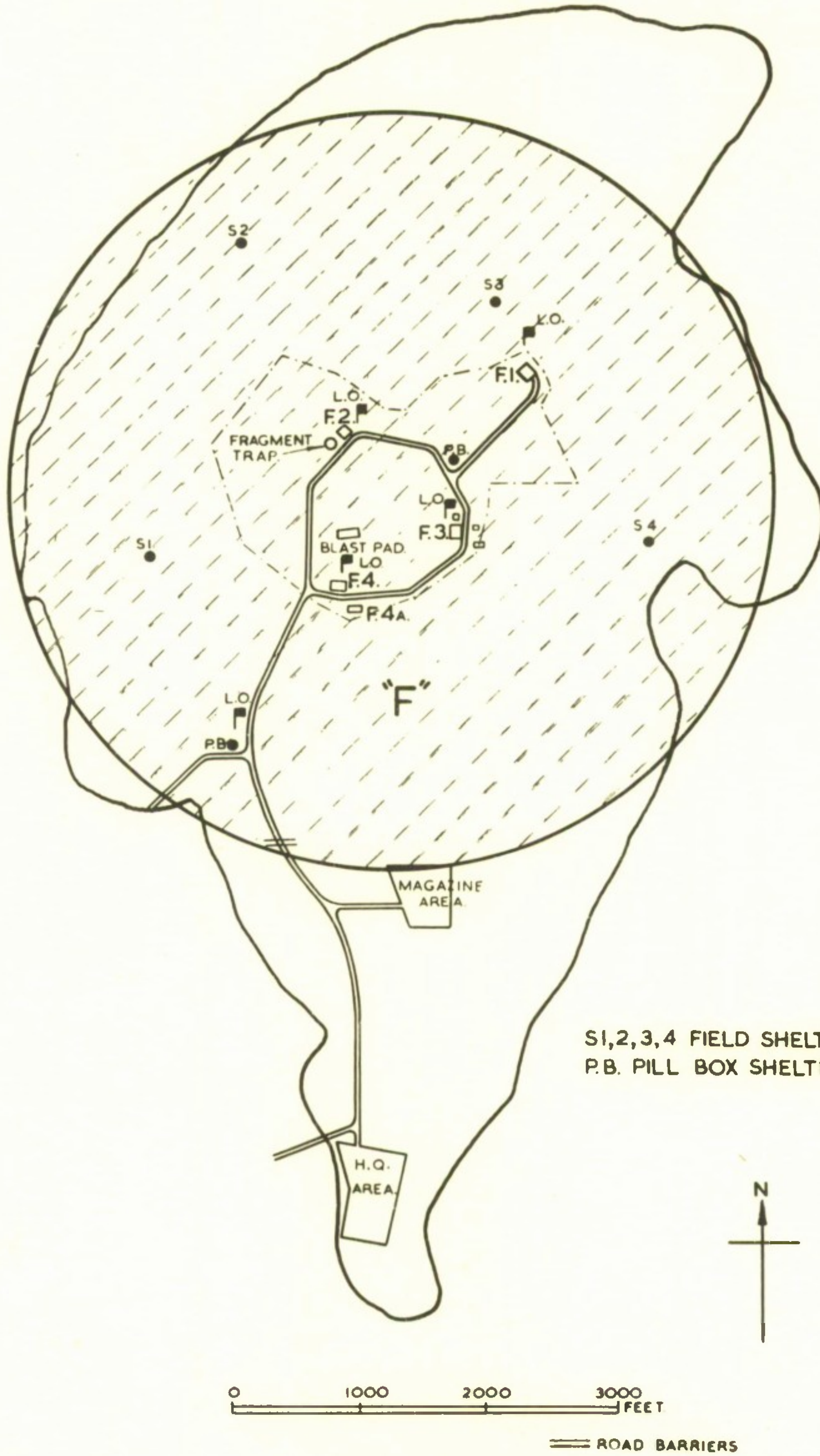
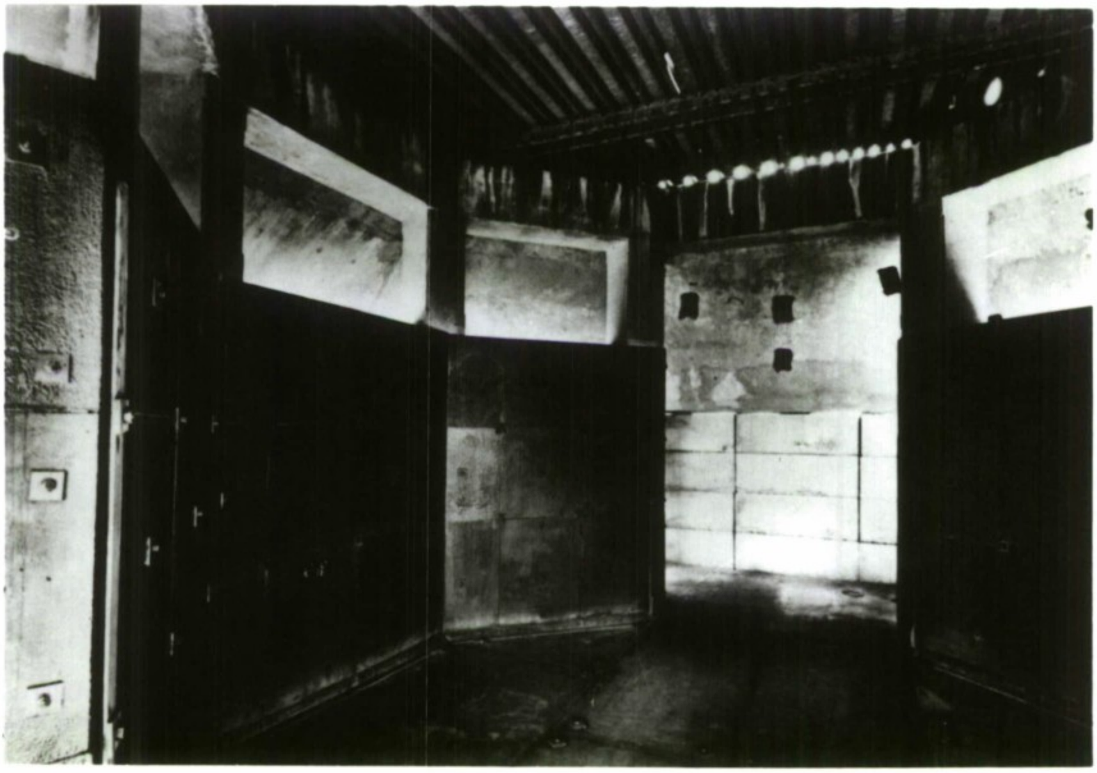


FIGURE -AREA "F"

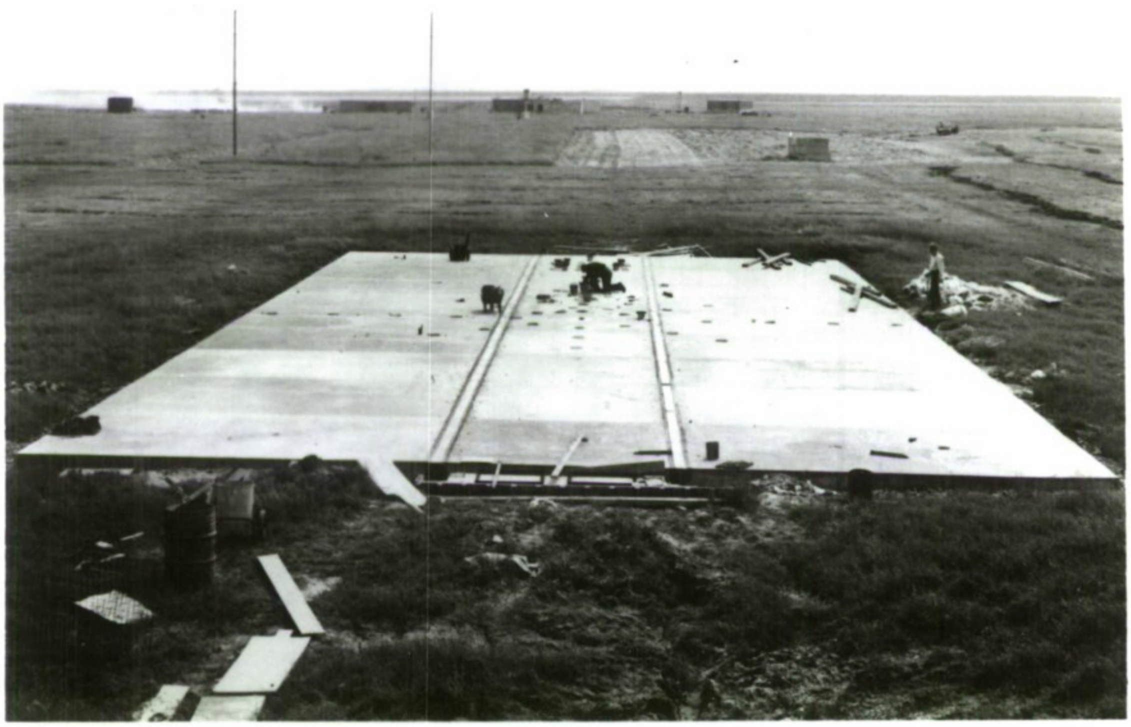
FULL COVER AREA

FIG. 4



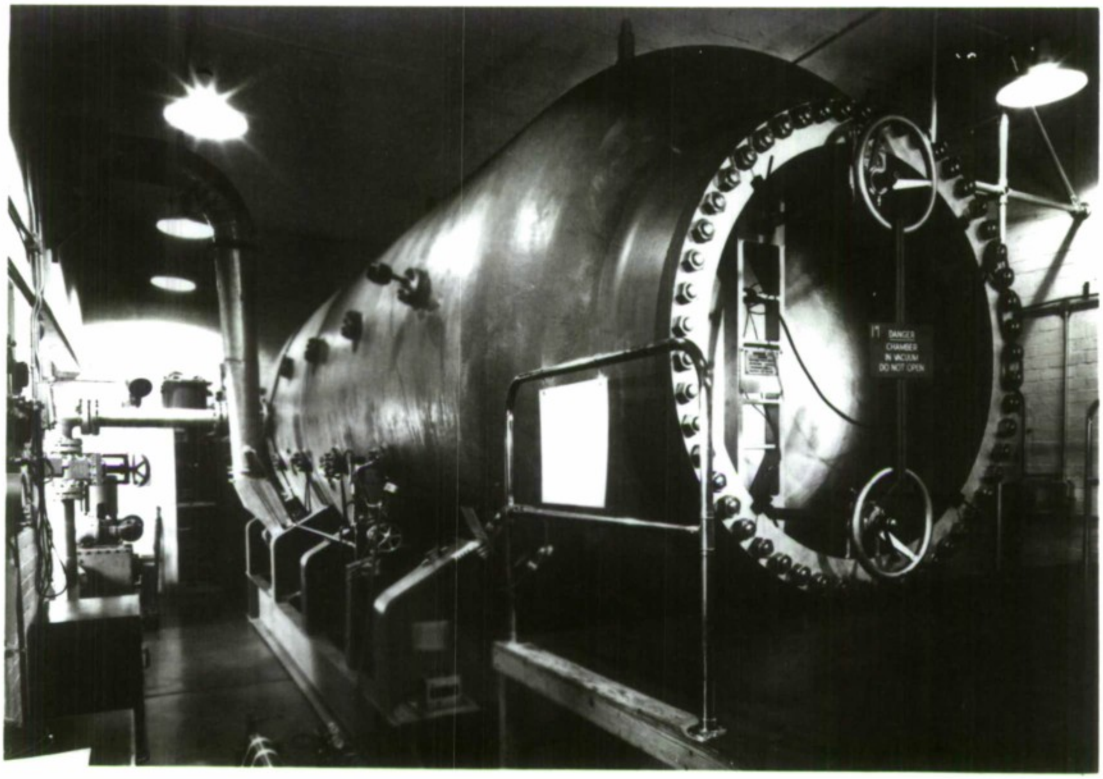
CASED - CHARGE FIRING BUILDING

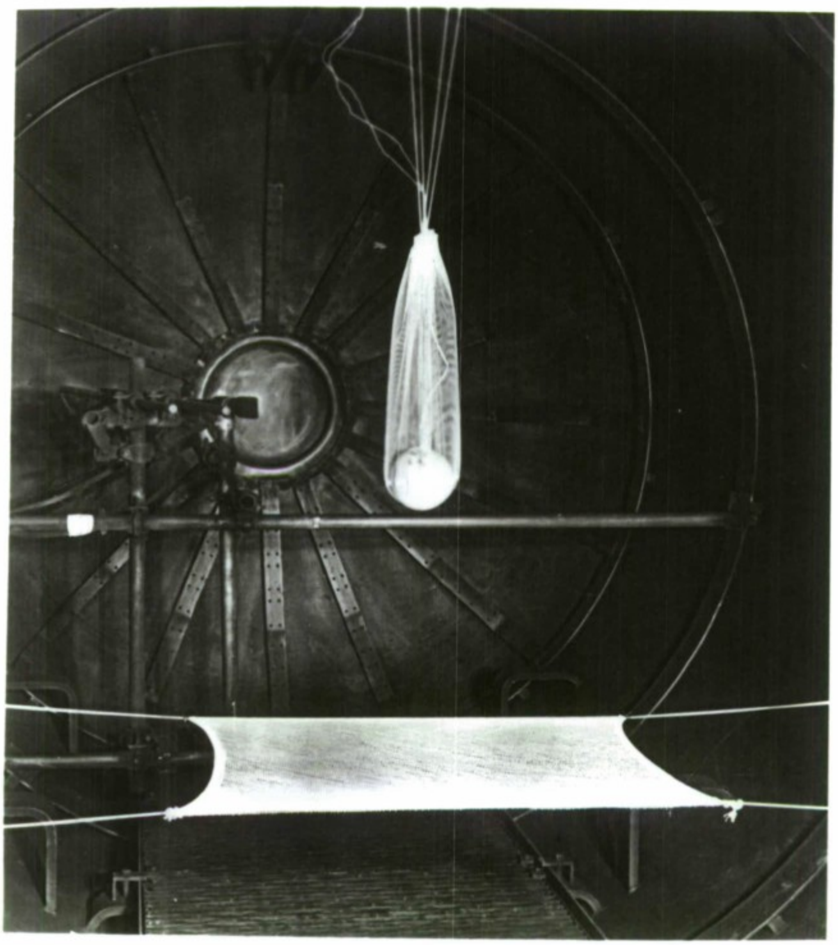
FIG. 5



BLAST PAD

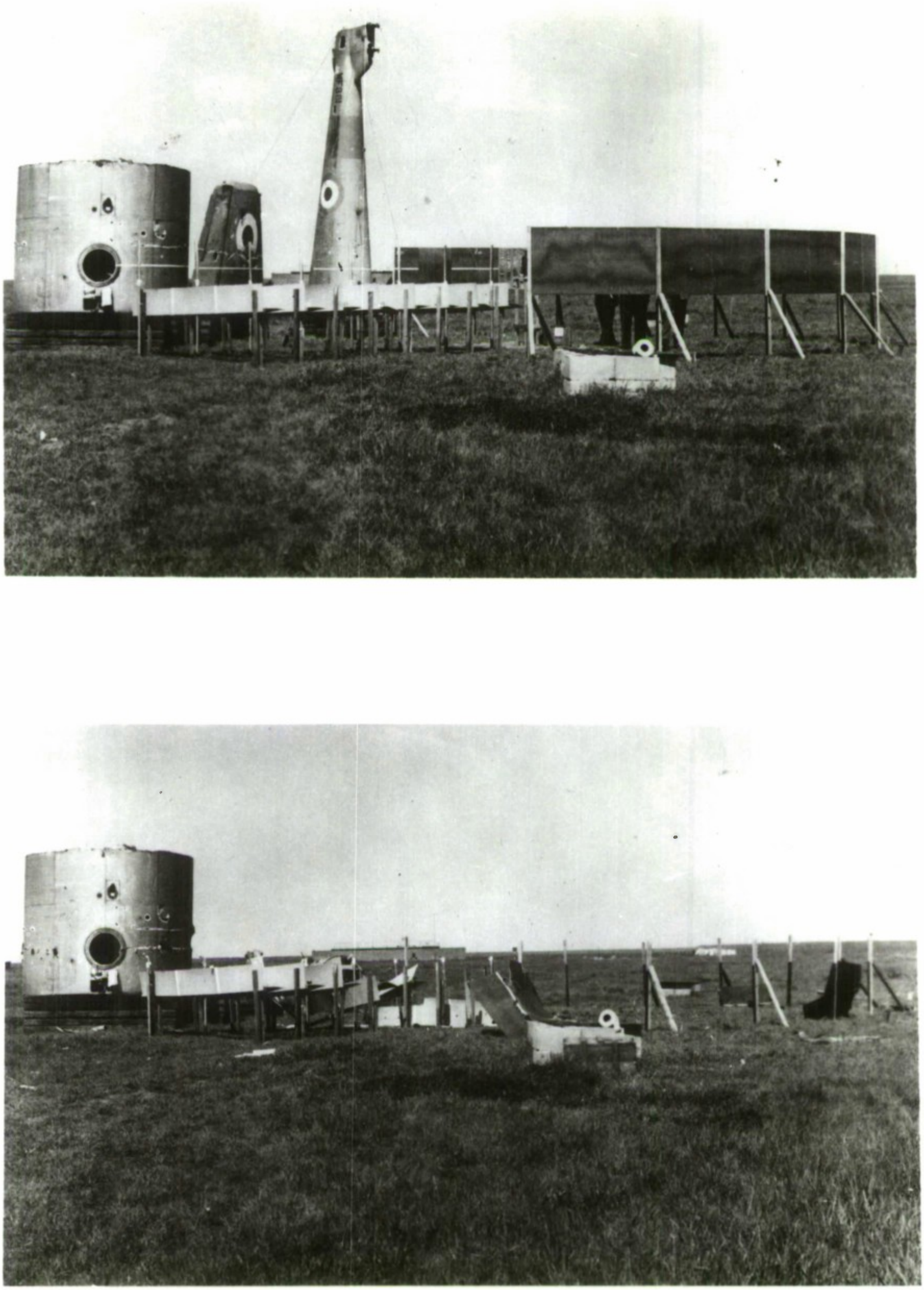
FIG. 6





HIGH ALTITUDE CHAMBER

FIG. 7



CONTINUOUS ROD WARHEAD TARGET AREA
BEFORE AND AFTER FIRING

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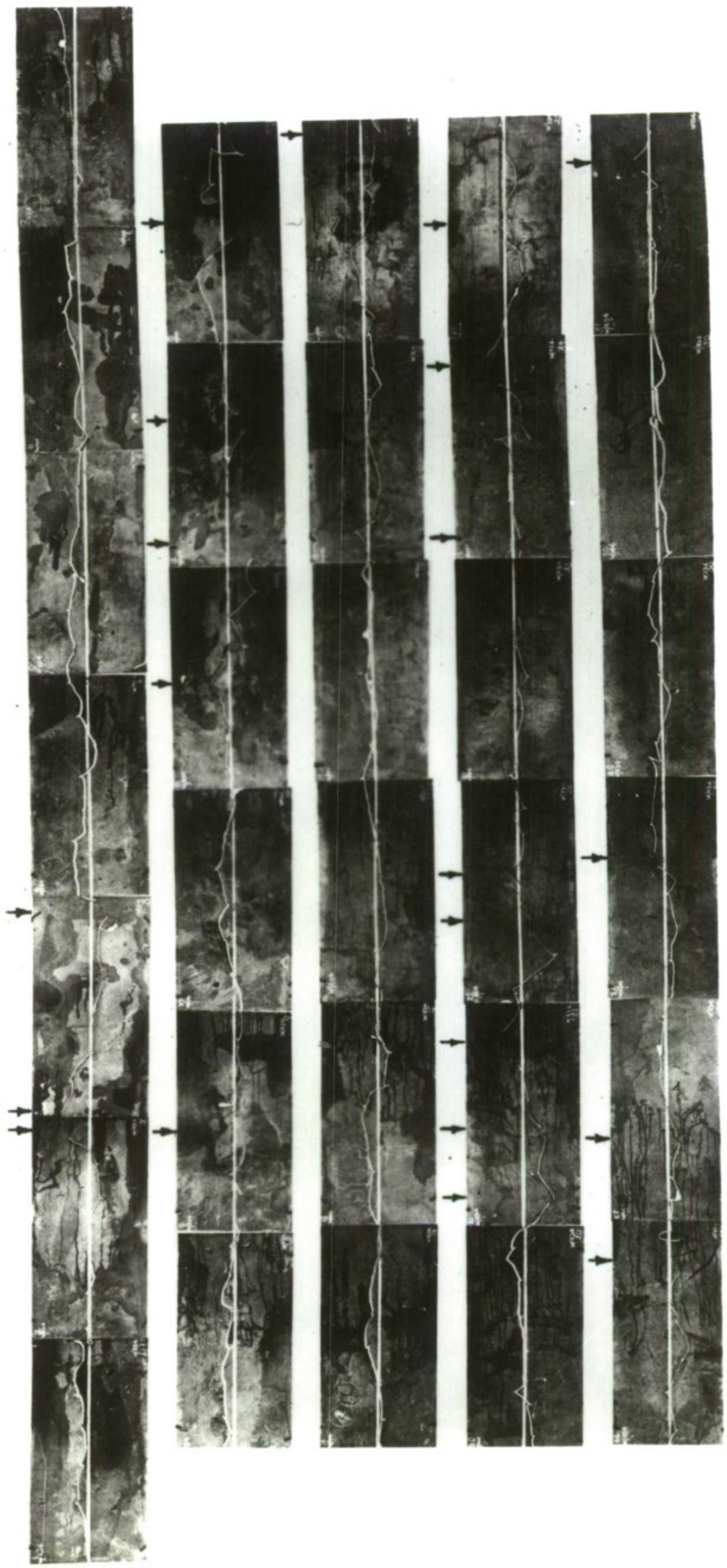
FIG. 8



WITNESS PLATES DAMAGED BY CONTINUOUS ROD WARHEAD

ARROWS INDICATE PLACES NOT CUT BY ROD

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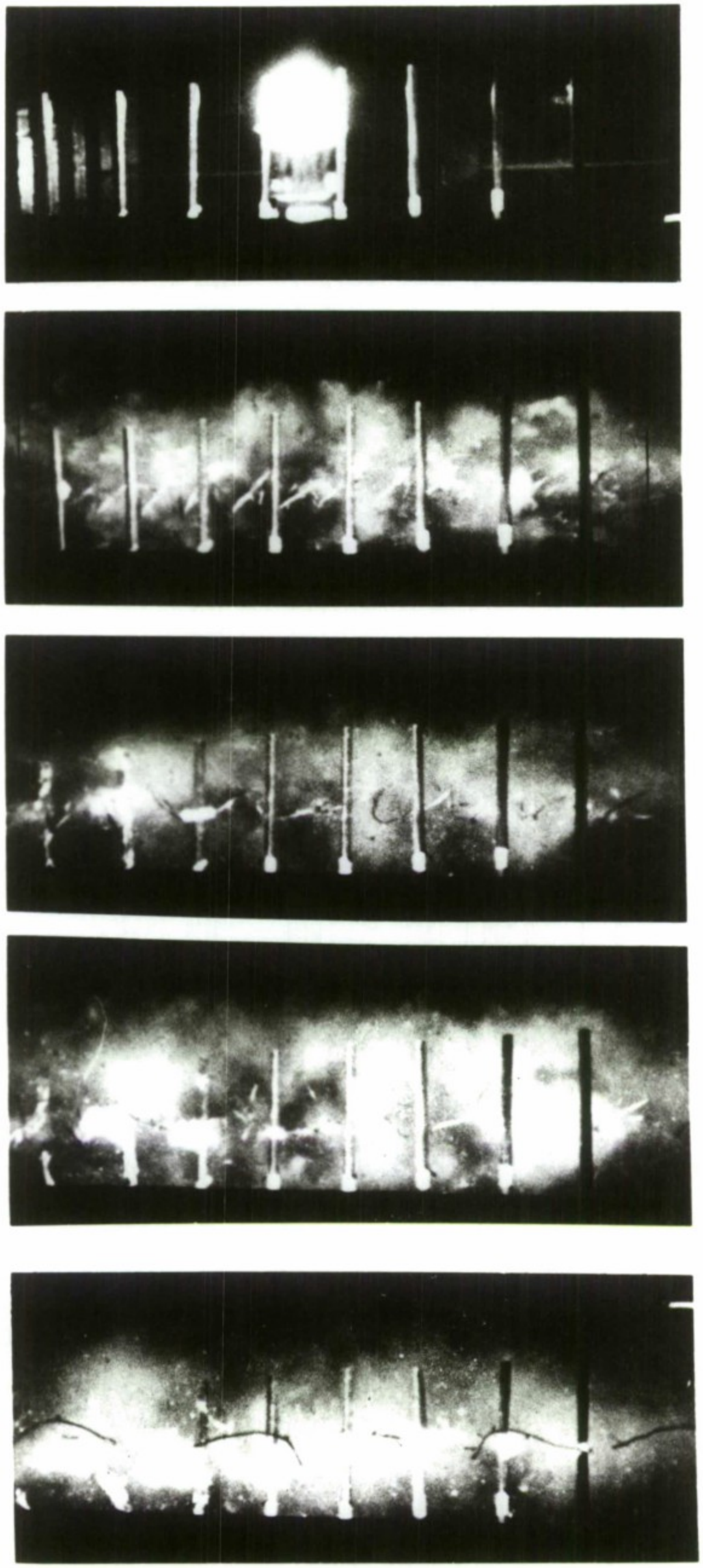
FIG. 9



DEVELOPMENT OF CONTINUOUS RODS IN FLIGHT
(FROM FASTAX CAMERA RECORDS)

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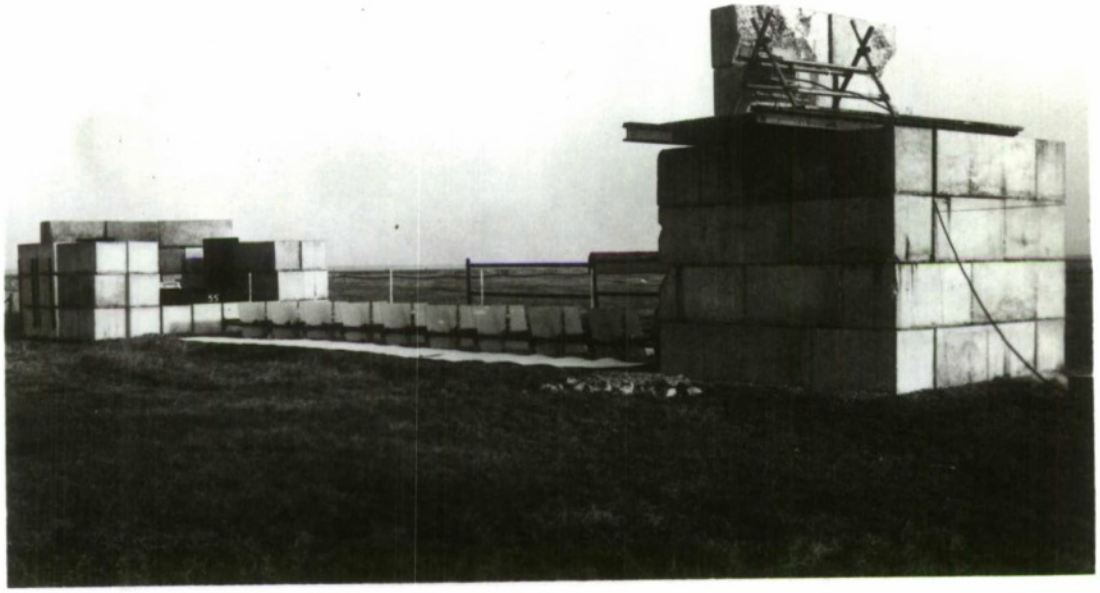
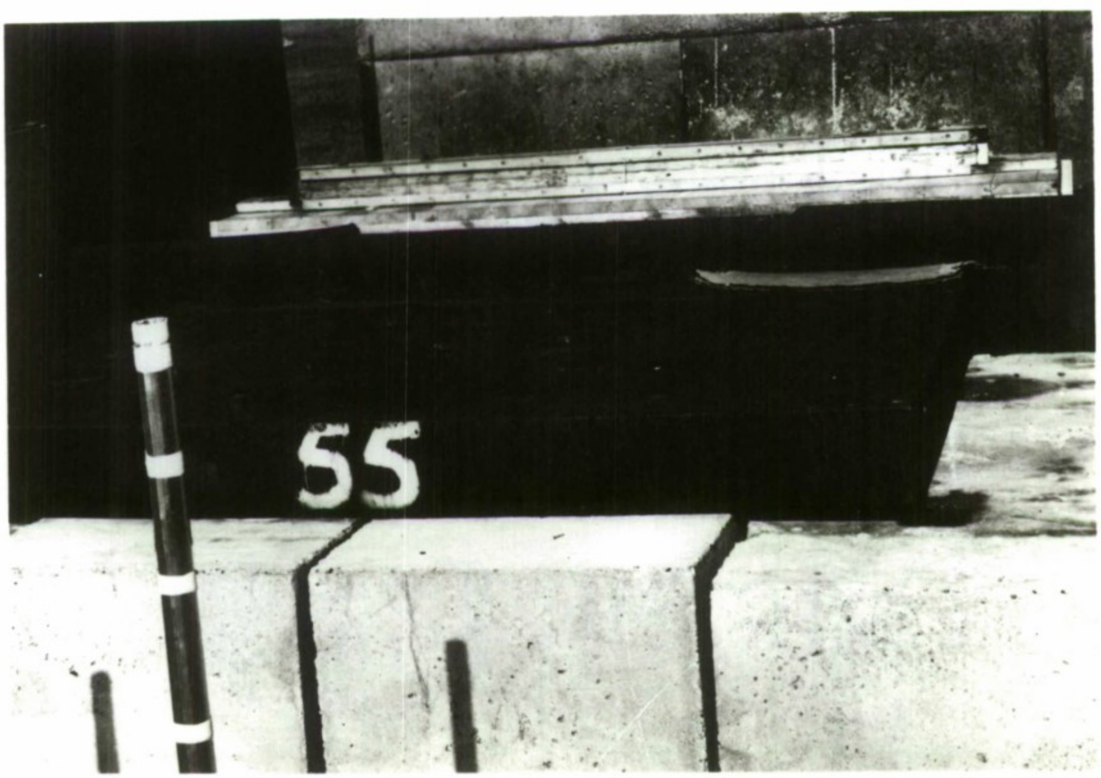
FIG. 10



FIRING LAYOUT

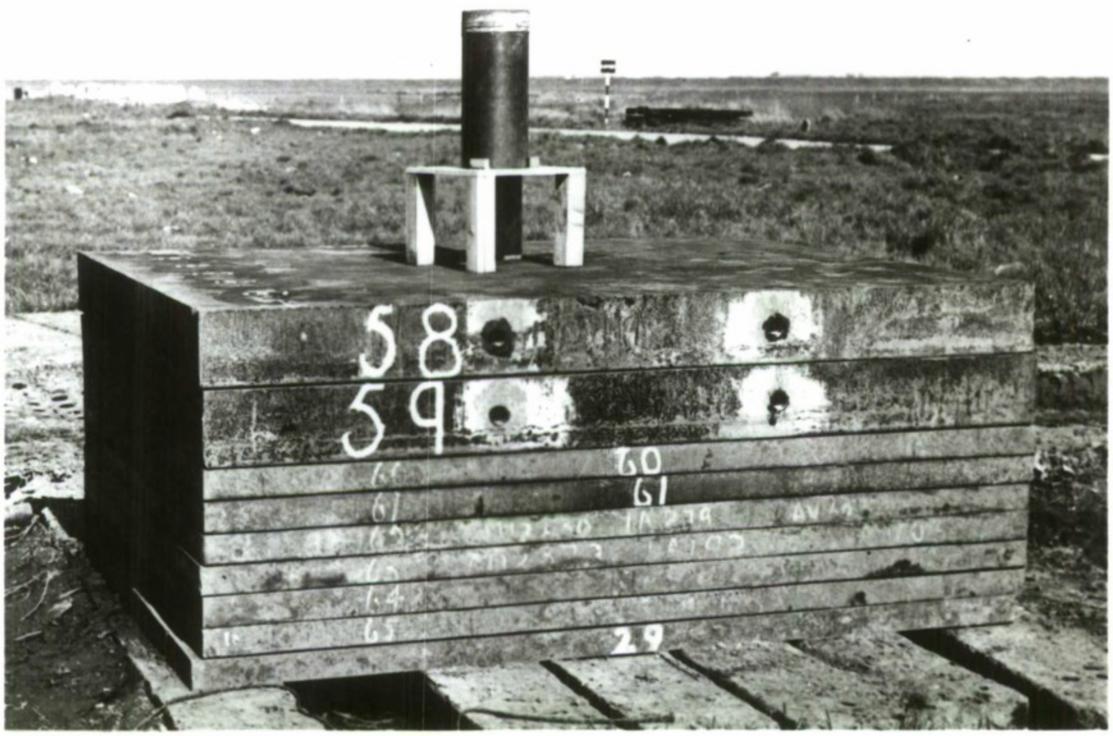


← CHARGE

CHARGE IN POSITION

ROD PROJECTOR

FIG. 11

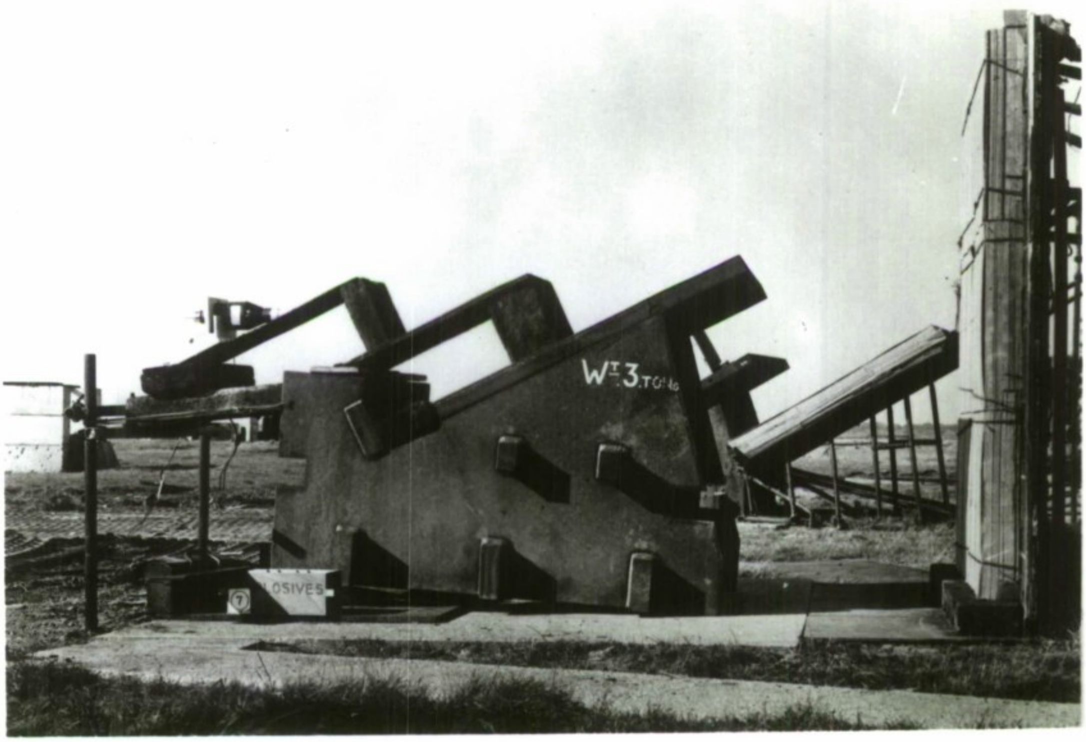


SHAPED CHARGE ON SEMI – INFINITE TARGET

FIG. 12

SINGLE TRIPARTITE TARGET

DOUBLE TRIPARTITE TARGET

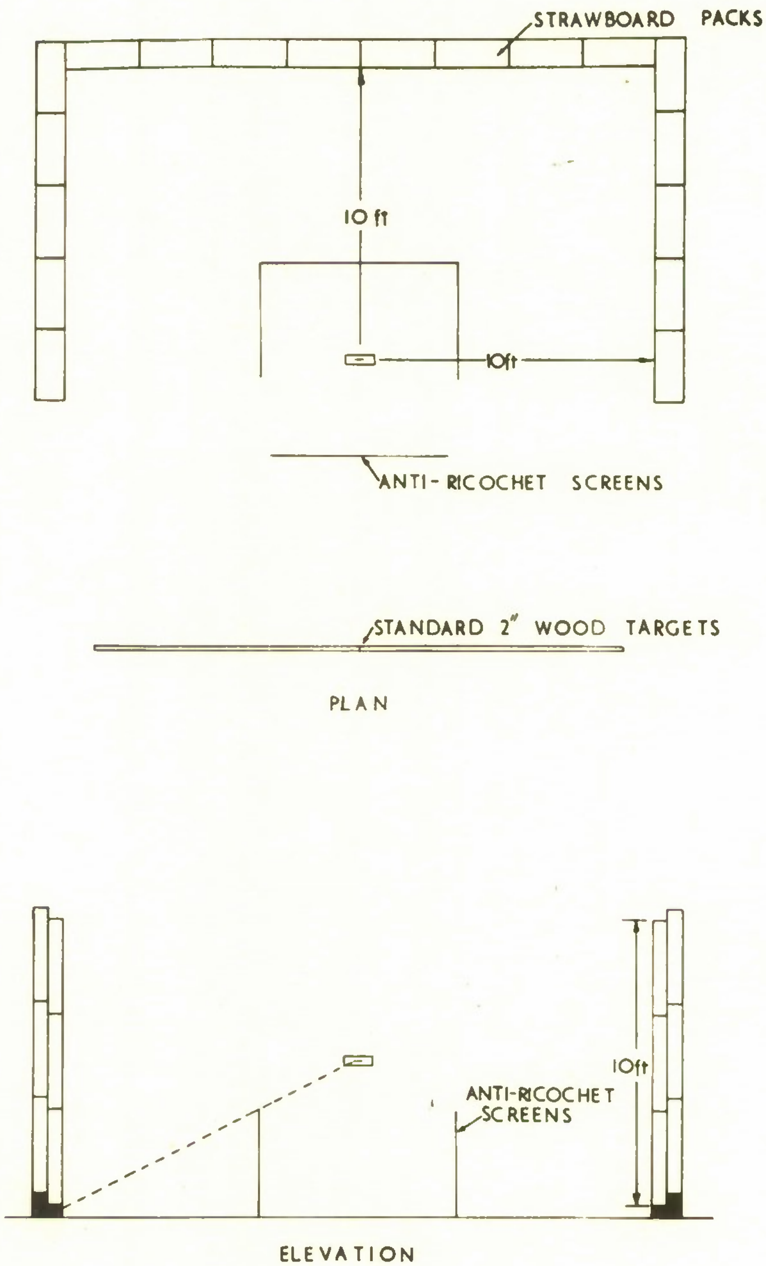


TRIPLE TRIPARTITE TARGET

FIG. 14

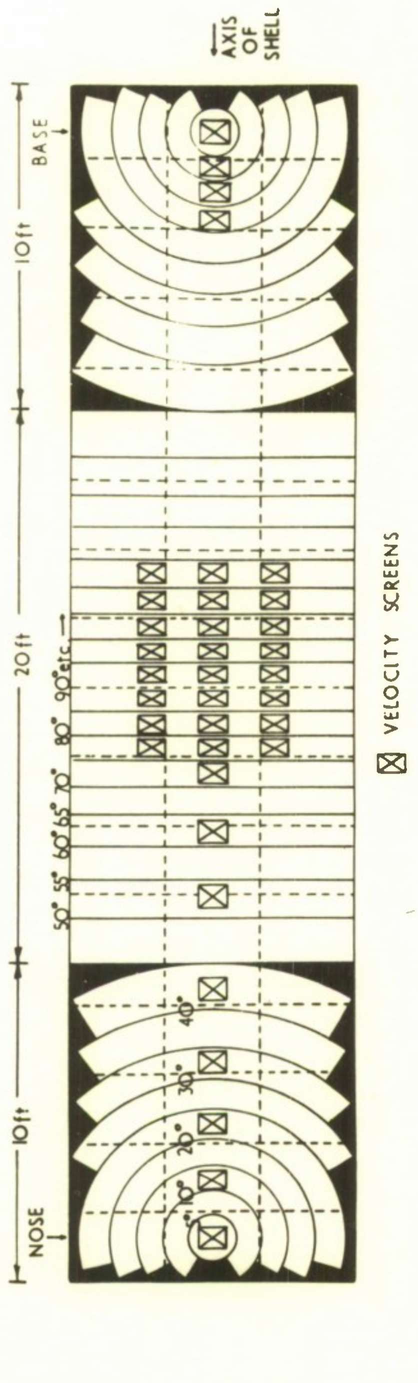
EXPLOSIVE FORMING – BASIC STUDIES

FIG. 15



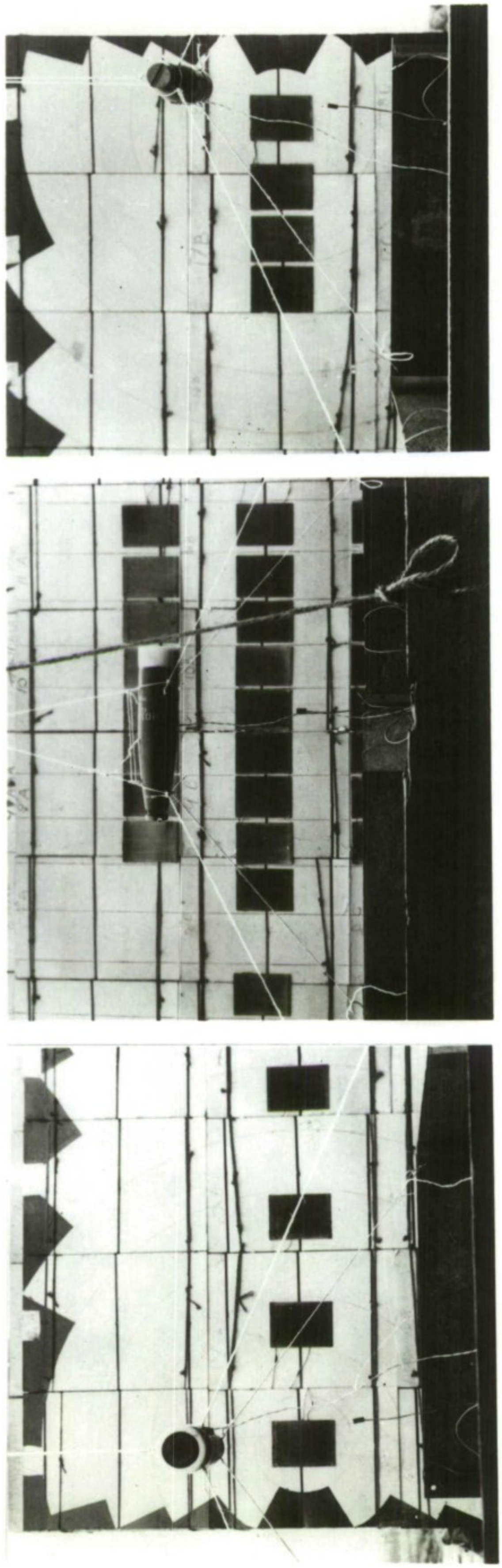
LAYOUT OF FRAGMENTATION TARGETS

FIG. 16



SHELL 105 MM. POSITION OF VELOCITY SCREENS AND MARKING OF TARGETS IN 5 DEGREE ZONES

FIG. 17



NOSE

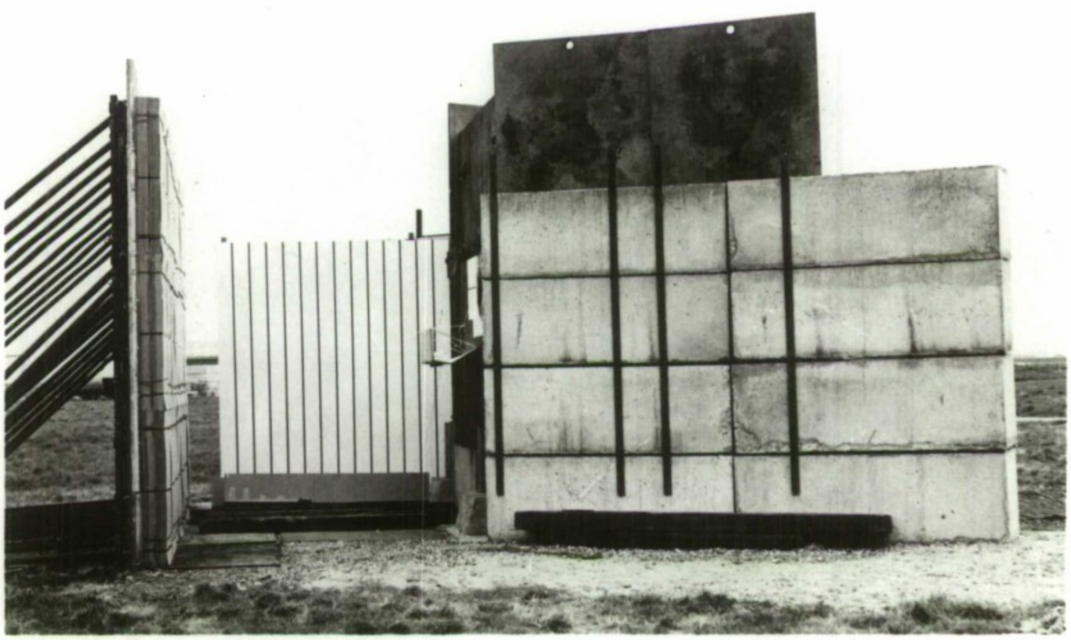
SIDE

BASE

105 MM SHELL IN FRAGMENTATION LAYOUT

FIG. 18

FRONT



SIDE

LAYOUT FOR STATIC H E S H TRIALS

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R.A.R.D.E. Memorandum 12/65 — 623.48:
53.087

The Potton Island Terminal Ballistics Trial Facility
G. R. Nice — April 1965

An account is given of the organisation and capabilities of the R.A.R.D.E. Potton Island Terminal Ballistic Trials Facility with an outline of the wide range of work undertaken from 1959 to 1963.

15 pp. 18 figs. 6 refs.

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